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AUTHOR Chiu, Mei-Hung
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ABSTRACT

The purpose of this study is to analyze the perceived thought processes of several students as they learn, and then attempt to solve problems about chemical equilibrium. Four tenth grade students in Taipei, Taiwan, were audiotaped as they individually attempted to solve problems. The problems were such that they required more than mere recall or algorithmic learning and yet simple enough to give the learners a reasonable chance of success. It was found that successful problem solvers generated coherent and meaningful explanations, while unsuccessful problem solvers' explanations for the examples tended to show their inconsistency of understanding. As for problem-solving tasks, successful students were characterized by giving better reasoning, use of relevant principles and concepts to justify their answers, frequent checks of the consistency of answers, and better quality of procedural knowledge. The results suggest the textbook used lacked sufficient information for all students to be able to develop knowledge and skills to solve the problems. (PR)

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DEVELOPING PROBLEM-SOLVING SKILLS IN CHEMICAL EQUILIBRIUM — A CONSTRUCTIVE MODEL*

Mei-Hung Chiu
National Taiwan Normal University
Graduate Institute of Science Education
Taipei, Taiwan

ABSTRACT

The purpose of this study is to analyze the perceived thought processes of several students as they learn, and then attempt to solve problems about chemical equilibrium. Four students were audiotaped as they individually attempted to solve the problems. The problems were such that they required more than mere recall or algorithmic learning and yet simple enough to give the learners a reasonable chance of success. The study was conducted in three phases: 1) a pre-test in which terminologies, daily life and content specific problems about chemical equilibrium were covered, 2) studying materials in a textbook containing diagrams, examples, exercises and tables, and 3) an alternative version of the pre-test as a post-test. Extensive use of the think-aloud protocols was used to analyze the approaches of the successful and unsuccessful problem solvers. It was found that successful problem solvers generated coherent and meaningful explanations, while unsuccessful problem solvers' explanations for the examples tended to show their inconsistency of understanding. As for problem-solving tasks, successful students were characterized by giving better reasoning, use of relevant principles and concepts to justify their answers, frequent checks of the consistency of answers, and better quality of procedural knowledge. Unsuccessful students had many knowledge gaps and misconceptions about the nature of the underlying principles. Finally, the results also suggest the textbook used lacked sufficient information for all students to be able to develop knowledge and skills to solve the problems.

*The author is grateful for the help of Hua-Wen Fu for transcription, data analysis and comments. I particularly appreciate the generosity of the students who contributed their time to this study.

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Introduction

Problem solving has captured the interest of a broad range of people concerned with education - teachers in the classroom, to the educational psychology researchers, textbook publishers, and national government agencies. Although each of these groups approaches the issue from a different perspective, there appears to be a consensus of opinion that one of the most critical educational tasks of current society is to enhance students' ability to think effectively.

The study focused on the nature of concept and problem-solving skills in science learning. In particular, the analysis will emphasize the latter issue. The researcher is studying the specific explanation skills that allow successful problem solvers to relate new information from examples in textbooks to knowledge they already have, and to create well-structured new concepts that will allow them to answer questions in which they must analyze, relate, and integrate information rather than simply repeating facts which they have memorized. The results of this proposed research will be reported to both the scientific community and to practicing teachers.

I. Objectives

The purpose of this research was to examine 10th graders' problem solving skills in an important part of chemistry, chemical equilibrium, after studying a textbook and worked-out examples. It was designed to answer three questions: 1) What is the nature of individual differences in learning from examples in chemical equilibrium? 2) What are the differences between the thought processes of "successful" and "unsuccessful" students

engaged in solving chemical equilibrium problems? 3) How do self-explanations generated by the learners subsequently enhance their construction of knowledge for solving problems?

II. Theoretical framework

Learning from examples

Increasing the problem-solving abilities of students continues to be a major goal of mathematics and science teachers. However, students have been criticized for lack of problem-solving proficiency (Stewart, 1982). In order to improve students' problem-solving abilities, research has shown that worked-out examples can improve students' learning in science, mathematics, and computer programming. For example, LeFevre and Dixon (1986) found that students actually prefer to use the example information and ignore the written instruction when learning a procedural task. Pirolli and Anderson (1985) found that 18 of their 19 novices relied on analogies to examples in the early stages of learning to program recursion. Sweller and Cooper (1985) obtained strong evidence showing that students who were given the opportunities to study model workings (i.e., example solutions) had advantages over students who were just given opportunities to work the problems. In addition, in a classroom study, Zhu and Simon (1987) have shown a clear advantage (a 3 year course can be reduced to a 2-year math curriculum) if students are given carefully chosen sequences of worked-out examples.

Chi, Bassok, Lewis, Reimann, & Glaser (1989) pinpoint that good students (i.e., those who had greater success at solving physics problems) learn with understanding - refining and expanding the conditions for the

action parts of the example solutions and relating those actions to principles in the text, whereas poor students rely heavily on examples during problem-solving. The differences in problem-solving characteristics reflect degree and quality of understanding of principles and concepts presented in a text. According to Chi and her colleagues (1989), they found that students must provide their own explanations for the whys and wherefores of each component step in an example solution in order to fully understand a worked-out example, so that the derivation of one action of the example solution from another makes sense. Chi and her colleagues referred to these inferences generated by the students as self-explanations.

Good problem solvers generate more elaborations and monitoring statements from studying with examples, while poor problem solvers neither provide a large number of statements nor accurately monitor their own comprehension. Not only do these studies show the importance of working with examples in the process of students' learning, but they also reflect how students can learn science in a more constructive and active way to help themselves build useful schemata, search for problem-solving strategies, and gain insights. This constructive aspect of students' learning was the major concern of this study.

The nature of expertise

Much research has been done in investigating learners' expertise. In the following section, some research in science education will be briefly discussed. According to Larkin, Heller, and Greeno (1980), the knowledge of experts is organized hierarchically and stored in the form of "large functional

units" composed of coordinated principles that are easily retrievable, while novices' knowledge is more fragmented and more difficult to access from long-term memory. In the area of biology, Stewart (1983), and Smith and Good (1984) described many differences in the way experts and novices go about solving a genetics problem. For instance, Smith and Good found that experts perceive a problem as a task requiring analysis and reasoning and they tend to use a knowledge-development approach. In a problem-sorting study in physics, Chi, Feltovich, and Glaser (1981) described experts as making classifications based on underlying principles of the domain (e.g., conservation of momentum, matter, energy), while novices handled the same problems according to the superficial information given in the problems. In chemistry, Gabel, Sherwood, and Enochs (1984) and Larkin and Rainard (1984) also examined the differences between novices and experts in stoichiometric problems. Their results show that successful students and those with high reasoning ability tended to use algorithmic reasoning strategies more frequently than unsuccessful and low reasoning ability students. Apparently, one of the most fruitful approaches taken by these researchers toward understanding the nature of problem solving has been the comparison of the performances of successful (expert) and unsuccessful (novice) subjects. However, we should keep in mind that the nature of students' performance is fluid rather than rigid.

Chemical equilibrium

Numerous studies have been done for understanding the difficulties of learning the concept of chemical equilibrium (Camacho and Good, 1989;

Gorodetsky & Gussarsky, 1986; Gorodetsky & Hoz, 1985; Gussarsky & Gorodetsky , 1990; Hildbrand, 1946; Johnstone, MacDonald, & Webb (1977); Wheeler & Kass, 1978). The research indicates that students have several typical misconceptions about chemical equilibrium; namely, failing to conceive the dynamic nature of the system at chemical equilibrium; failing to conceive the mixture at chemical equilibrium as a single entity and consequently manipulating each side of the chemical equation independently; inability to identify the systems to which the principle applies and applying the principle to a given system with erroneous results; and lack of abilities to differentiate rates of reaction from rate constants, etc. Abraham, Grzybowski, and Renner (1992) reported that textbooks failed to teach a reasonable understanding of chemical concepts.

Within these studies, only a few have been done related to knowing the mechanism of the problem solving process for chemical equilibrium (Camacho and Good, 1989). Camacho and Good found that (1) most novices showed a large number of knowledge gaps about the taxonomy of chemical equilibrium constants (e.g., Kc, Kp, Ka, Kb, Ksp); (2) most experts demonstrated proper specific knowledge of chemical equilibrium by applying several principles (e.g., gas laws, thermodynamics laws) to justify their answers and reasons; while most novices showed many basic misconceptions and lack of access to important concepts; and (3) several kinetics misconceptions appeared to be intermingled with thermodynamics concepts, such as lack of knowledge about the difference between rates of reaction and rate constants. To solve problems in chemical equilibrium, a student needs to understand the taxonomy of chemical equilibrium constants, possess specific

content knowledge and be able to use chemical-mathematical skills. However, research indicates that students are unable to apply their knowledge to problem-solving process.

It is an important aspect of problem-solving to examine how students learn chemical equilibrium concepts and when their misconceptions occur in order to implement our teaching instructions and materials. Therefore, it is the focus of this study.

III. Method

The subjects. Four 10th graders (two males and two females) from a local high school in Taipei, Taiwan, voluntarily participated in this research at the end of the 10th grade. Subjects were individually interviewed by the researcher using the think-aloud method. With this method subjects were given tasks and asked to describe how they learned the materials and how they were solving the task. The data consisted of a transcript of each interview and written work which the subject produced. All the experiments were tape-recorded for the sake of transcription and analysis. The researcher stressed to the subject that more interested in how the answers were reached rather than the final answers.

There are two reasons to choose 10th graders. First, they have not learned the intended topic. In this way, the outcomes of their learning from the materials are more consistent. Second, according to task analysis of the intended material (Science Education Center, 1989), our subjects should have been taught necessary prerequisite knowledge and skills for learning chemical equilibrium at their 8th, 9th, 10th grades.

The textbook. Chemistry (volume 2) is a standard textbook for high

school students in Taiwan. The text is self-contained with diagrams, examples, exercises, and tables. The concepts of chemical equilibrium are covered in Chapter 6 which is always taught in the second semester of 11th grade. The target chapter includes the topics of equilibrium constant, Le Chatelier principle, the effect of added reagents, the effect of pressure, the effect of temperature and catalyst, and equilibrium calculations. One session in the textbook dealing with solubility product (Ksp) was beyond the study subjects' abilities and was excluded from the treatment.

The procedure. There were four phases to the study:

1. An interview session (a pre-test) in which each student discussed:
   (1) what they knew about 20 terms (i.e., reversible reaction, catelyst, etc.) related to chemical equilibrium (named Type 1 for later analysis),
   (2) eight daily experience problems relating to equilibrium (Type 2, taken directly from the end of the chapter of a physical science textbook), and
   (3) thirteen content-specific questions (Type 3).

   This interview was audiotaped.

2. Each student then read the 32-section chapter. Each section was printed on a separate piece of paper according to its topic. A prompting consisted of general instructions given in the beginning of the reading phase, then the students were told to explain their understanding of the section. Students often did this out with no difficulty. In addition to these general prompts, a number of specific prompts were inserted at 33 locations throughout the chapter. These locations corresponded to places in the text at

which an idea about chemical equilibrium was discussed, such as reaction rate. We therefore evaluated how well they learned during study and then contrast this result with their performance on the posttest. Students were told that they may also take notes and draw diagrams while reading, although they were not prompted to do so.

3. After reading the main part of the chapter, students were asked to study three worked-out examples in the text, and then they were requested to solve a set of problems. This set consisted of five "chapter" problems, which were problems taken directly from the end of the target chapter and three problems selected from a reference book (after consulting a high school chemistry teacher) to correspond with the content of worked-out examples in the previous step. The students were allowed to look back on those examples during problem-solving but no feedback was provided.

4. After they finished the material, a post-test, an alternative version of the pre-test, was conducted individually. This interview was audiotaped.

The whole treatment and evaluation lasted for 3-5 sessions with each session spaced a week apart. Each session lasted from 1-3 hours. All sessions were audiotaped.

IV. Results

Students' performance

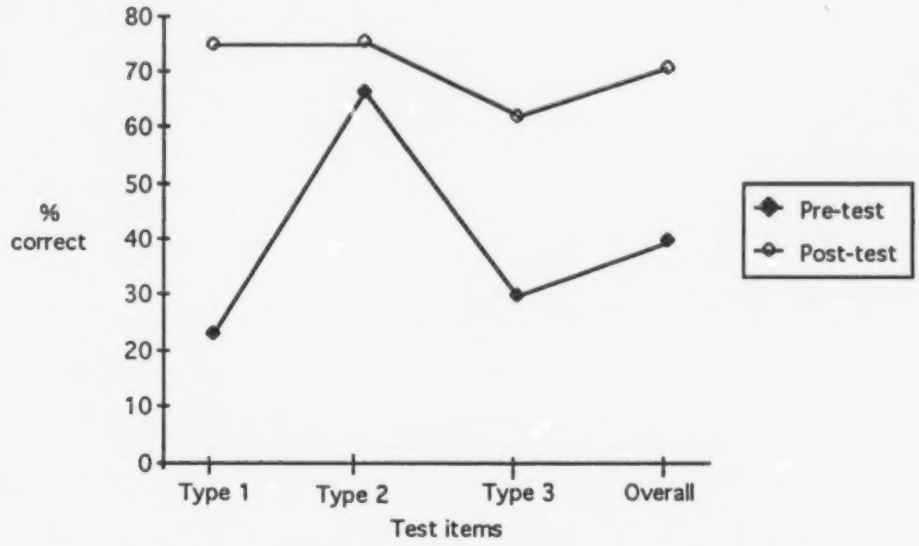
Students' answers on all categories of questions showed improvements in their performance (Table 1). The overall percentage of correct answers on the pre-test was 40.46 and the overall percentage of correct answers on the post-test was 71.39. The greatest amount of gains was in Type 1 questions

(51.87%) and Type 3 questions (31.96%), which was predictable since these questions tap information that was presented in the chapter (Figure 1). The least amount of improvement occurred in the Type 2 questions (8.96%), since their performance in the pre-test was already higher than the other two types, the students had less of a chance for improving their scores (ceiling effect).

Table 1. Percentage of correct answers on the pre- and post-tests and each individual category.

	Overall	Type 1	Type 2	Type 3
Pre-test	40.46	23.75	66.92	30.72
Post-test	71.39	75.63	75.89	62.68

Figure 1. Students' performance (% of correct answers) on the pre- and post-test.



Students were characterized into two categories (successful and unsuccessful students) based on their performance on the problem-solving task. Each problem had a maximum score of ten points, with partial credit available depending on the answer. The successful students (2) were scored 65.83%, whereas the unsuccessful students (2) were only scored 30.63% (Table 2). The students' performance on the post-test and prompted questions were consistent. In other words, the successful problem solvers performed constantly better on their post-test than those unsuccessful problem solvers. In addition, the successful students showed better understanding of the text on the prompted questions than the unsuccessful students (93.56% versus 80.30%, respectively). These findings suggested that students who performed better on the problem-solving task (procedural knowledge) tended to show better declarative knowledge.

Table 2. Percentage of correct answers on the problem-solving and prompted tasks.

	Problem-solving	Prompt
Successful	65.83	93.56
Unsuccessful	30.63	80.30

Table 3 shows the percentage of correct answers on the overall and individual category of test items on the pre- and post-tests by ability. There was little difference between the more and less successful students in the amount of prior knowledge that they came into this learning task, since they had about the same scores on the pre-test (42.37 % versus 38.55%, respectively). The successful students averaged 76.65% correct answers on the post-test, whereas the less successful students averaged 66.13% correct answers on the post-test. The successful students also outperformed the unsuccessful students in all three types of questions. Figure 2 is a breakdown of student scores according to the three types of questions assigned.

Table 3. Percentage of correct answers on the overall and individual category of test items on the pre- and post-tests by ability.

		Overall	Type 1	Type 2	Type 3
Successful	Post-test	76.65	81.25	77.95	70.76
	Pre-test	42.37	27.50	67.65	31.95
Unsuccessful	Post-test	66.13	70.00	73.82	54.59
	Pre-test	38.55	20.00	66.18	29.48

Figure 2. Means for percentage of correct answers on pre- and post-tests (including the subtests) categorized by ability.

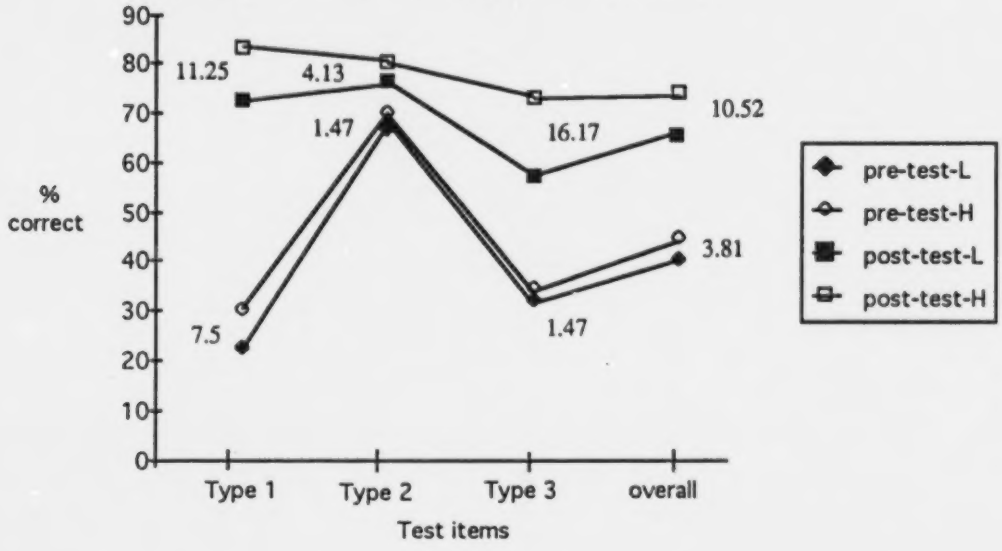
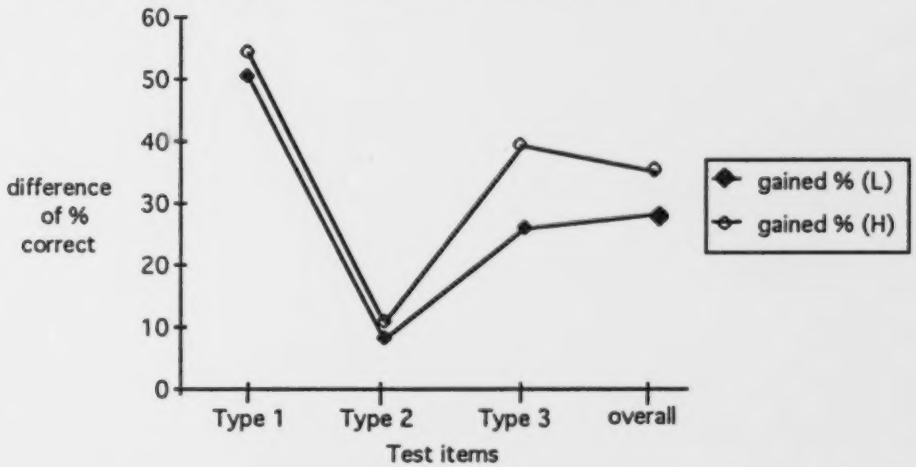


Table 4 shows that the biggest gains for successful students were in Type 1 (53.75%) and Type 3 (38.81%) which taped information explicitly presented in the text while the smallest gain was in Type 2 (10.3%) primarily due to a ceiling effect. Similarly, the unsuccessful students gained the most on Type 1 and Type 3 questions (50% and 25.11% respectively) and gained very little on Type 2 questions (7.64%). This result is again consistent in that the more successful students uniformly answered more questions correctly than the less successful students in all categories of questions (See Figure 3).

Table 4. The gain scores on the overall and individual category of test items performance by ability.

	Overall	Type I	Type II	Type III
Unsuccessful students	23.77	50.00	7.64	25.11
Successful students	38.10	53.75	10.30	38.81

Figure 3. Percentage of correct answers for each type of question categorized by ability between pre-test and post-test.



Note-taking

In addition to talking out-loud, students were encouraged to take notes while reading the materials. Students' notes were categorized into: re-producing the sentences (equations or diagrams), re-organizing the information, raising questions, and making connections. As they generated notes, they were asked to elaborate on their understanding about the present information. The number of notes taken was recorded.

As Chi, de Leeuw, Chiu, and LaVancher (1992) point out, drawing diagrams may be an effective constructive activity for enhancing learning. However, diagrams was rarely used in the process of learning chemical equilibrium by these students. Instead, the successful students took more detailed notes in other forms, as indicated above, to help themselves understand the concept of chemical equilibrium than the unsuccessful students (18.5 notes versus 12.5, respectively). Smith and Good (1984), similarly, found experts use accurate and detailed bookkeeping procedures in learning. Notetaking by students should be investigated with more students to permit more detailed analysis. The quality and the contents of these notes may provide useful information about student learning.

Study time and Learning from examples

Knowing students' performance on the problem-solving, pre- and post-tests, we might wonder how their time was spent on the task. The successful students spent more time on all the activities (including reading the materials, studying the examples, and solving problems) than the unsuccessful students. For instance, the successful students took a longer time to elaborate the materials and to make summaries (1 hour 45 minutes and 29 seconds), whereas the unsuccessful students spent a shorter time on studying and elaborating the materials (1 hour 23 minutes and 7 second). This information was obtained from the amount of explanations they generated while studying.

Similar results were found both in learning from examples and in the problem-solving process. The successful students spent a longer time on

examples than the unsuccessful students (14 minutes and 13 seconds compared to 8 minutes and 17 seconds, respectively). In learning from examples, successful students tended to make themselves understand the interrelationships among the problem solving procedures. For example, the successful students explained the steps in the following example below.

Example 1: 6 moles of nitrogen and 16 moles of hydrogen were confined inside a 2 liter container, and allowed to reach equilibrium at 638 K. At equilibrium the sample contained 8 moles of NH_3. Calculate the equilibrium constant for the reaction at the temperature of the experiment.

Solution:		N_2 (g)	+ 3 H_2(g)	2 NH_3 (g)
Step 1:	Initial moles	6.00	16.00	0
Step 2:	Moles reducted	-4.00	-12.00	+8.00
Step 3:	Moles at equilibrium	2.00	4.00	8.00
Step 4:	Concentration at equilibrium	1.00	2.00	4.00

$$Kc = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{(4.00)^2}{(1.00)(2.00)^3} = 2.00$$

Subject L01: "... the initial moles are 6:16:0, then moles reducted..Oh.. since it produces 8 moles of NH_3, yah, it uses..uses 12 moles of hydrogen and 4 moles of nitrogen. Yah, so the moles at equilibrium are 2:4:8 In other words, there are 2 moles, 4 moles, and 8 moles.... since they are inside a 2 liter container, so divided by 2....yah, there are 1, 2 and 4.... the stoichiometric coefficient [1, 3, 2] in the balanced equation should be raised to the power of each concentration, and then substitution of all three equilibrium concentrations into the expression for Kc... so the equilibrium constant equals to 2.

There are two striking findings. First, the successful students explicitly and correctly interprets the definition of equilibrium constant. Second, the successful students learned with understanding from the example by making judgements of each procedure and drawing conclusions from the presented information.

However, the unsuccessful students explained the same steps in a completely different way which showed an incorrect understanding of the example in which the textbook presented incomplete information. The protocols are shown below:

> Subject Y01: "In the beginning, N_2 has 6 moles and H_2 has 16 moles. We found N_2 has only 2 moles, H_2 has 4 moles when the reaction reaches equilibrium....and the NH_3 changes its moles from 0 to 8 moles. The reduction in the moles of components is equal to the initial moles minus the moles at equilibrium, that is the reduction of moles... We found the N_2 decreases 4 moles and then H_2 decreases 12 moles, NH_3 increase to 8 moles...."

There are two main misunderstandings. First, the subject worked out this example backwards: he used Step 3 to explain how the Step 2 was produced. This indicates a misunderstanding of the procedures: an error in reasoning. Second, the unsuccessful student showed an incomplete and poorer quality of understanding of the examples: he did not explain how those moles were generated in relation to the coefficients in the balanced equation.

Examining their explanations from studying the examples, we might

be able to detect where their miscomceptions are from, where they were occurred, and when they confronted with problems during their learning.

Problem solving

Knowing the successful students scored higher on the prompted questions and spent longer time to understand the examples, we might expect them to complete the problem-solving task quicker. Surprisingly, the results indicate that the successful students spent longer time (88 minutes and 44 seconds) than the unsuccessful students (56 minutes 33 seconds) on solving the eight problems. Extensive analysis of think-aloud protocols revealed that the successful students showed a high motivation to complete the task even when they had impasses, whereas the unsuccessful students tended to give up their work when difficulties arose.

The successful students were also able to use knowledge from another domains (i.e., mathematics) on their current task, whereas the unsuccessful students lacked chemical-mathematical skills for success. For instance, although all the students were unable to make proper simplification by approximations (e.g., 0.2-x ~0.2) to justify that the concentration of hydrogen (or carbon dioxide) minus the degree of reaction is equal to the concentration of the hydrogen (or carbon dioxide) (See Appendix Problem 2), the successful students were able to solve a quadratic equation for x and even to judge which of these two solutions is physically meaningful. While the unsuccessful students tended to reply "I don't know how to solve this quadratic equation." or "It's too complicated." Lack the ability to use knowledge and skills from another domains nor apply them to current tasks has been discussed in many studies. It is shown again in this study that the

unsuccessful students were unable to apply mathematical skills in problem-solving in chemistry.

The successful students were able to learn more from their experience of solving the problems. That is, the successful students were able to relate the previous questions to the current questions. The results also reveal that they used the previous strategies for solving a current task. This back and forth reference was found frequently, in particular, for those questions next to each other. This finding is consistent with Nisbett and Ross (1980)'s research in which they call it as vividness criterion. The following excerpts illustrate this finding:

In problem #3:

C01: assume that H_2 uses x mole concentration so I plug it into Kc to get the value of x... OK.. wait, how can I solve this equation...

E : What can you do?

C01: Let me see... no [try to decompose the coefficients] ... anyway, if I can get the value of x and then I can obtain the concentration of each substance.

In problem #5:

C01: Again, I have to solve this quadratic equation... let me try to use square root of b minus 4ac divided by 2a to see if I can get the x

E: OK.

C01: Something is wrong..

E: Mm..

C01: OK, I have to calculate them carefully, do the square root first... you got two values. Both are correct !... Wait, should be this one [point to one of them.]

E: OK.

In problem #6:

C01: The initial concentration is zero, the concentration reducted is x... so [plug them into the formula of Kc] it becomes $0.005-0.15X+X^2$... minus 0.75X... [again she used the same method as she did in problem #5]. The X equals 0.015 and 0.335... the concentration of Fe^{3+} is negative with 0.05-0.335. It does not fit.

E: OK.

C01: There must be one incorrect answer in problem #5 which I forgot to check.

E: Do you want to look it up?

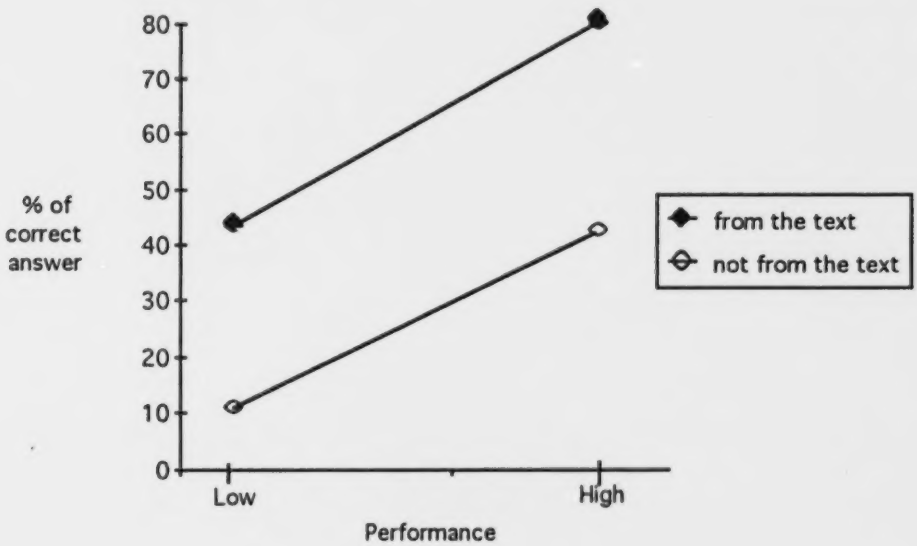
C01: Sure ! [check the previous problem] See, the concentration of SCN^- is negative if you check the answer again.

As discussed before, students were characterized into successful and unsuccessful groups based on their performance on the problem-solving task. In Figure 4, it shows that both successful and unsuccessful students have higher overall scores on problems (Type I) taken directly from the textbook than those taken from another sources (See Table 5 for scores). Also, the successful students had higher scores than the unsuccessful students on both types of questions. The results indicate that the students learned better on the questions taken from the end of the chapter. However, the students learned less on those questions taken from outside the text but related to the content. It suggests that the students show some difficulties in successfully using the principle involved in the example in a different and more complex problem, because such problems prevent students from being able to solve them via a syntactic mapping. As Swell and Cooper's research (1985) indicates, students who have studied examples often cannot solve problems that require a very slight deviation from those studied (eg., example solution).

Table 5. Percentage of correct answers on problems both from and not from the text by problem-solving abilities.

	Student	
	Successful	Unsuccessful
From the text	80%	43%
Not from the text	42%	10%

Figure 4. Percentage of correct answers for problems taken and not taken from the text by ability.



In sum, there are several major findings.

First, the students learned from the text and from the examples. They gained the most on the terms of chemical equilibrium and content-specific questions which were covered in the chapter.

Second, the "successful" students were able to apply problem solving skills from mathematics to chemistry, whereas "unsuccessful" students gave

up their problem solving task when facing difficulties.

Third, "successful" students generated their explanations which made their understanding of the examples coherent and meaningful, while "unsuccessful" students' explanations for the examples tended to show their inconsistency of understanding.

Finally, the findings also suggest that a major shortcoming of the textbook is the lack of sufficient information for solving problems, since such information is necessary for successful problem-solving and meaningful understanding.

V. Conclusions

The findings of this research indicate that students read the examples with different degrees of understanding. The unsuccessful students used more surface features of examples to solve problems, while the successful students were able to understand the deep structure of the principles in the examples and then apply them properly during problem solving. The successful students provide explanations for relating the situation to the principles and concepts in the text, which in turn serves to further understanding. However, to some extent, the text still does not provide explicit instructions and necessary skills for unsuccessful problem solvers. The results indicate that example exercises should be designed to provide conditions for the chemical reaction, practice chemical-mathematical skills, and relate the chemical reactions to Le Chatelier principles.

Interesting results were obtained from this research, but the results are inconclusive because of the small sample. For future research, data need to be

obtained from a larger sample to permit greater generalization. The study suggests some possible mechanism for how the constructive learning process can play an important role in enhancing students' understanding of domain principles and concepts.

Appendix

Samples for Chemical Equilibrium Problems Used

1. The equilibrium constant at 750^{O}C for the reaction $H_{2(g)} + CO_{2\,(g)}$ <-----> $CO_{(g)} + H_2O_{(g)}$ is Kc = 0.771. Suppose a 5.0 liter container was filled with 1 mole H_2 and 1 mole CO_2. Calculate the concentration of the mixtures at equilibrium.
2. In an equilibrium system, $Fe^{3+}(aq) + SCN^{-}(aq)$ <-----> $FeSCN^{2+}(aq)$, $[FeSCN^{2+}] = 0.1M$, $[Fe^{3+}] = 0.1M$, $[SCN^{-}] = 0.2M$. Calculate the equilibrium constant. Suppose we add some water to double the volume of the original solution. What is the final concentration of Fe^{3+} ?

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Signature: Mei-Hung Chiu	Position: Associate Professor
Printed Name: Mei-Hung Chiu	Organization: National Taiwan Normal University, Graduate Institute of Science Education
Address: NTNU, GISE, 88, Sec 4 Ting chou Rd. Taipei, Taiwan 11718	Telephone Number: (02) 932-2756 Ext 223
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